35 ELEKTOR

March 1978

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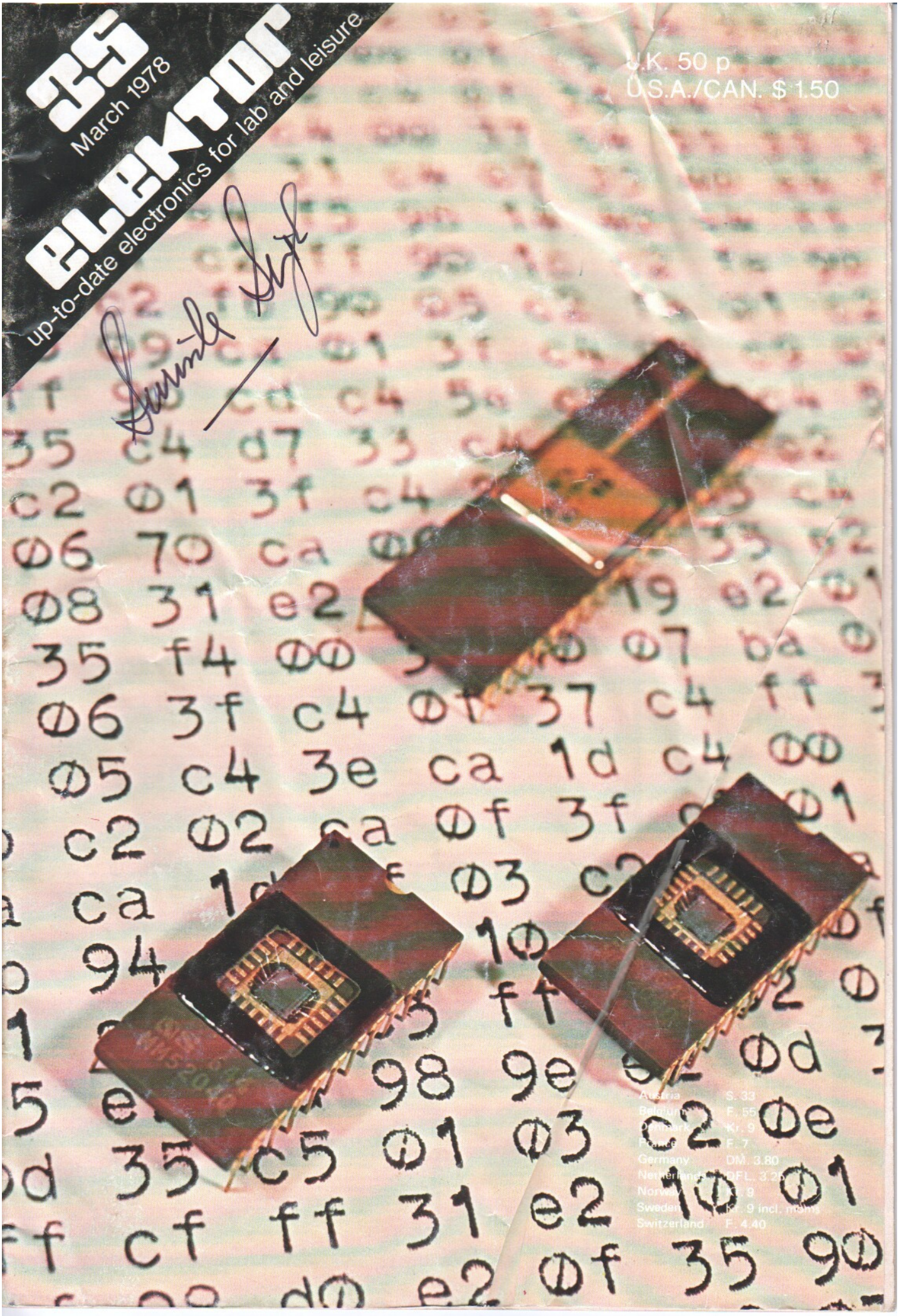

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colour TV games

Playing games like tennis on a TV screen has become quite popular, and several manufacturers supply suitable integrated circuits. Regrettably, most of these ICs suffer from one drawback: built-in obsolescence! In a competitive market every manufacturer is bent on outdoing his competitor, either by offering a chip that will do the same job cheaper or by designing a chip that will offer more features for the same price: more games, on-screen scoring, sound, colour,... National Semiconductor have recently introduced a novel solution to this problem: a family of pin-compatible ICs, offering on-screen scoring, sound and colour (either NTSC or PAL), some interesting handicap features, and a growing number of games. This means that the same circuit and printed circuit board can be used with more versatile chips when they become available.

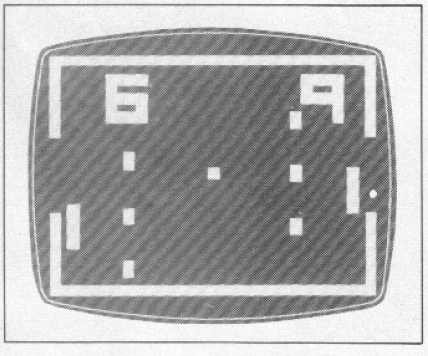
The oldest member of the family is the MM 57100, which was designed for use with the North American colour TV transmission system NTSC (National Television System Committee; an alternative interpretation is Never Twice the Same Colour). In several European countries, including Great Britain, the PAL (Phase Alternation Line, or Pay for Additional Luxury) system is currently employed for colour broadcasts, and National Semiconductor have introduced the MM 57105 for use with this.

Both 24-pin chips contain all the logic gating needed to generate the field of play, bats, ball, sound effects and score for three different games: Tennis, Hockey and Squash. In addition they supply the necessary chrominance information, so that in conjunction with the colour modulator IC LM 1889 (suitable for both NTSC and PAL) a colour picture is displayed on the screen. The circuit can equally well be used with a black-and-white receiver, although the picture obtained will, of course, not be in colour . . . . .

The third member of the family is the MM 57106. This IC is suitable for the NTSC system and offers a choice of six games. A PAL version of this chip is expected in the not-too-distant future, as well as a new NTSC IC which will offer 12 games. It should be noted that the 3, 6 or 12 games offered are fundamentally different: a 'practice' or 'solo' version of an existing game is not counted separately.

The descriptions given in this article are based mainly on the MM 57105, the PAL 3-game version. The modifications required for NTSC will be dealt with separately.

The vertical position of the bats is controlled by means of external slider- or rotary potentiometers. To vary the degree of difficulty of each game three different sizes of bat are available. For Hockey and Tennis, it is possible for one player to have a smaller sized bat than his opponent, thus providing an effective handicapping system for players of differing skill. In Squash, the size of the bat can also be modified, but in this case both players must use the same size of bat. To alter the size of a bat it is first shifted to the extreme upper or lower edge of the screen and the reset button is then pressed. At each successive touch of the button the bat changes first from large to medium size, then from medium to small, and finally from small back to large. The reset button also has the function of zeroing the score counter (0 : 0).



A notable feature of this games chip is the amount of control afforded over the direction in which the 'ball' is struck. The bats are 'divided' into nine different sections, each of which reflects the ball at a particular angle (regardless of the angle that the ball was travelling before it hit the bat). The two sections in the middle of the bats will return the ball in the horizontal direction. The three sections above and below the centre of the bat reflect the ball towards the upper and lower side boundaries respectively. The nearer the ends of the bat the point of contact is, the steeper the direction of reflection becomes. Finally, the circuit has a last little trick, in that if one strikes the ball with the lower edge of the bat, then the ball is 'spun' upwards towards the wall at the top of the screen, simulating a 'wood' or handle shot.

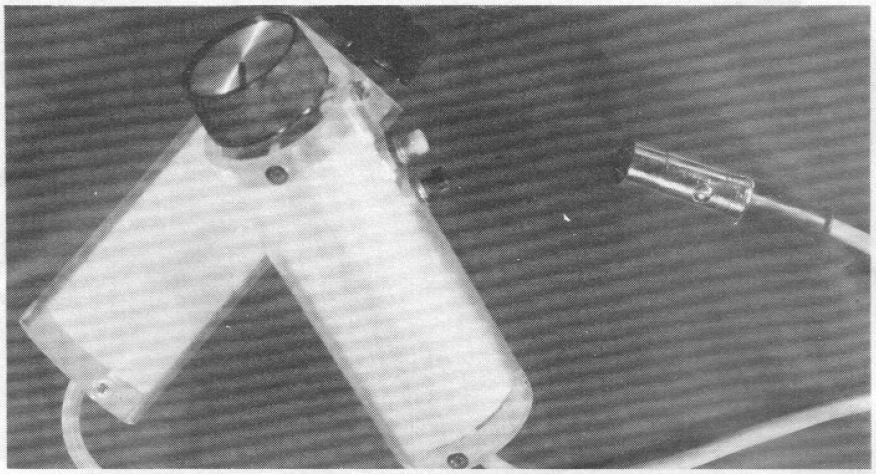
When the ball strikes one of the boundaries or a machine-generated 'bat' as in Hockey, then the angle of reflection always equals the angle of incidence.

The circuit also generates bat/boundary 'hit' and scoring sounds, which are rendered audible via the audio stage and loudspeaker of the TV receiver. This means that a separate loudspeaker is not required.

The ball is always served by the player who won the last point. First the score is displayed for approximately 1.5 seconds; then it is automatically blanked and the ball is put into play. To allow for a more 'realistic' situation where the server can 'place' his shot, the ball is served from the bat. Note, however, that it leaves the bat at the same angle as the preceeding shot, so a certain amount of skill is required!

After the fourth stroke of a 'rally' the difficulty of the game is automatically increased by the speed of the ball being doubled.

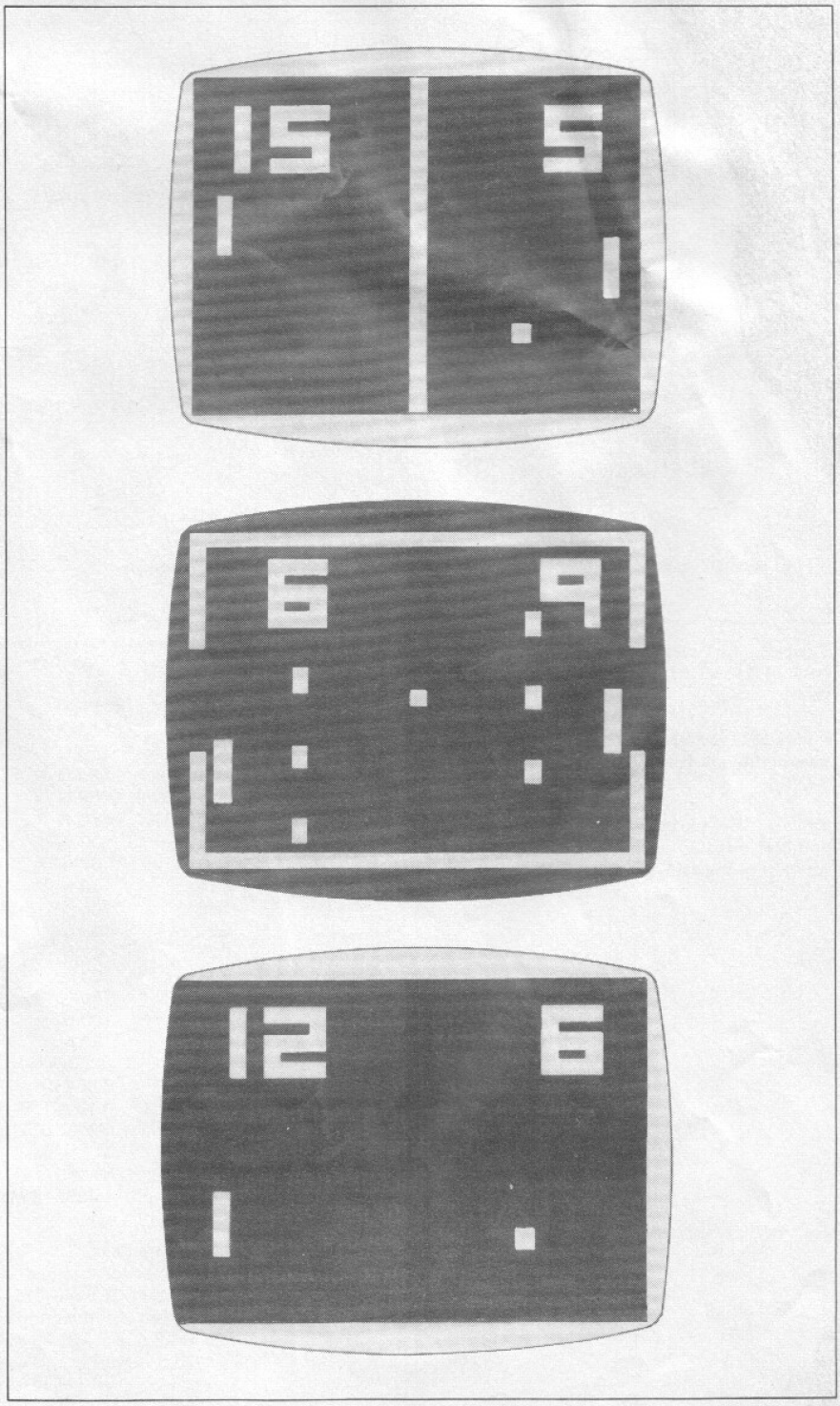
When the score reaches 15 the game is



ended and the automatic service is stopped. A new game can be started by pressing the 'reset' button.
A different game can be selected at any time by means of the 'game select' button. When this button is pressed repeatedly the chip steps through the possible games. This is one of the reasons why conversion at a later date to a 6- or 12-game version can be accomplished by simply inserting a new IC.

The circuit

Figure 1 shows the circuit diagram of the TV games system. The existing number of games can be extended to include 'solo' or 'practice' by moving switch S2 into the 'synchronous' position. Potentiometer P1 then ceases to affect the corresponding (right-hand) bat, both bats now being controlled synchronously by potentiometer P2. In this way it is possible to play against oneself.
In addition to the video-signal, the MM 57105 supplies the necessary colour information such as, e.g. the chroma and colour burst signals. The LM 1889 is a video modulator IC which combines all the functions of a colour signal mixer/modulator, reference frequency oscillator, sound channel oscillator/modulator, composite video modulator and RF channel oscillator.
The stability of the chroma subcarrier frequency (which can be varied slightly by means of the trimmer capacitor C13) is maintained by the 4.433618 MHz crystal. The divide-by-3½ counter MM 53114 (IC2) divides down the oscillator frequency to 1.266748 MHz. (Note that for the NTSC version this IC will be replaced by the pin-compatible type MM 53104). This signal and its inverted form are then fed to clock inputs 13 and 15 respectively of IC1, where they are used to derive the line and field sync pulses.
The tunable oscillator coils L2 and L3, details of which are given in the parts list, may be replaced by self-wound air coils. The diameter of these coils should be 6 mm, with 9 turns of enamelled copper wire (0.9 mm dia., or 20 SWG) for L2 and 7 turns for L3. Both coils should be close wound. In order to be able to tune the oscillators when using these coils, capacitors C17 (82 p) and C19 (100 p) should be replaced by trimmer capacitors (2 . . . 27 p).
The outputs of these oscillators contain harmonics extending up into the UHF band, and for this reason a bandpass filter is included, consisting of R19 . . . R22, C22 . . . C27, L4 and L5. These coils may also be self-wound: using the same diameter and wire as for L2 and L3, 3 turns are required for L4 and 6 turns for L5. The passband of this filter lies between 50 and 70 MHz, which is just wide enough to allow through only channels 3 and 4 in the



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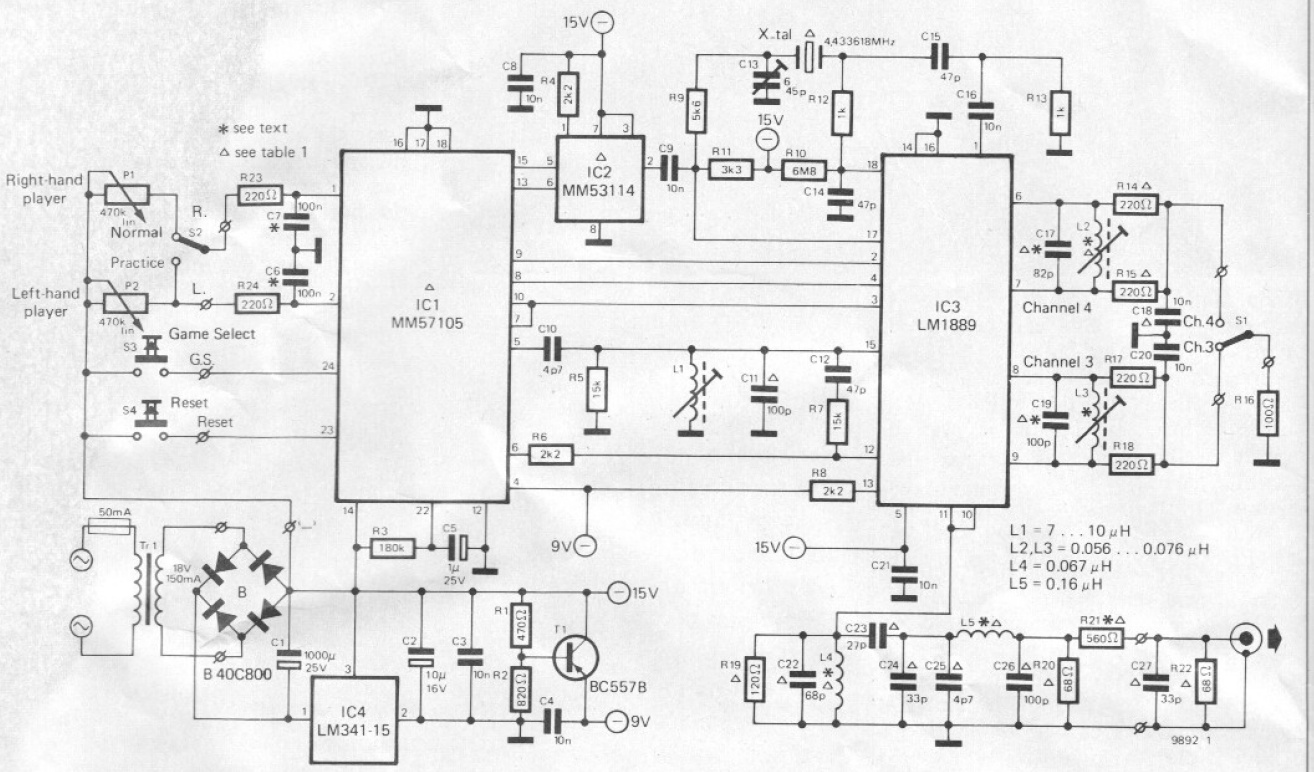


Figure 1. Complete circuit diagram of the basic (PAL VHF) version of the colour TV game.

Figure 2. Printed circuit board and component layout for the PAL TV game (EPS 9892).

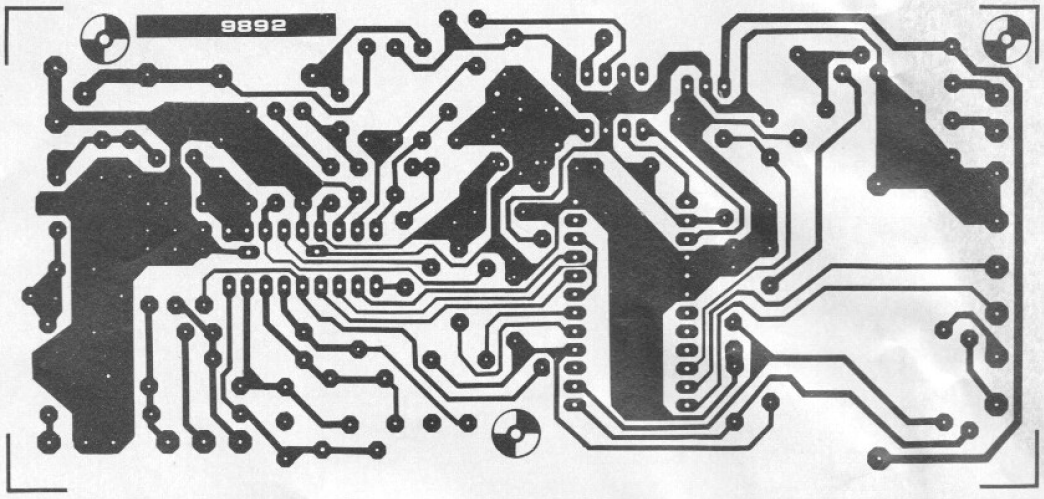
Table 1. Component values and IC type numbers, insofar as they differ for the three versions of the game.

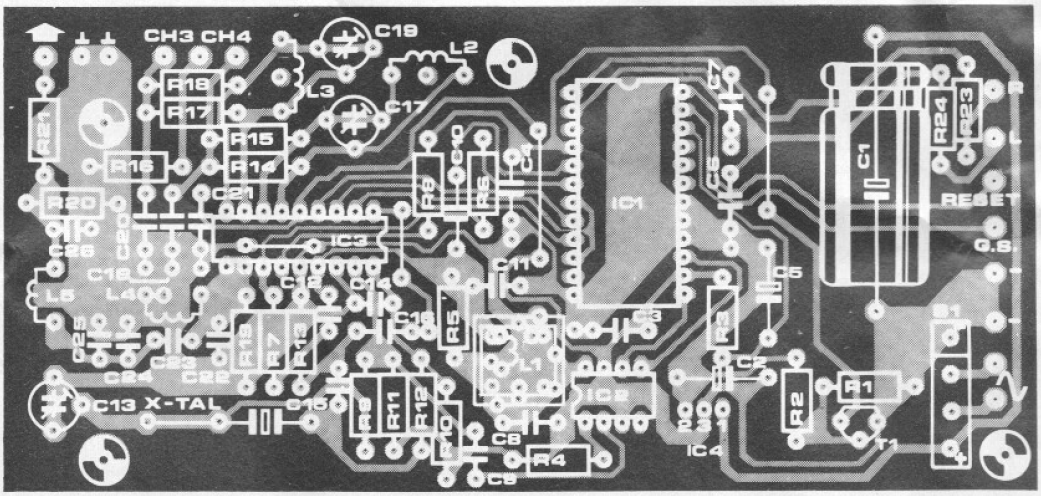
Table 1

	PAL VHF	NTSC VHF	PAL UHF
R14,R15	220 Ω	220 Ω	–
R19	120 Ω	120 Ω	–
R20,R22	68 Ω	68 Ω	–
R21	560 Ω	560 Ω	w.l.
C11	100 p	150 p	82 p
C17+	82 p	68 p	–
C18	10 n	10 n	–
C19+	100 p	82 p	100 p
C22+	68 p	68 p	–
C23+	27 p	27 p	56 p
C24	33 p	33 p	180 p
C25	4p7	4p7	–
C26+	100 p	100 p	–
C27+	33 p	33 p	–
L2	as L3	as L3	–
L4	0.067 µH	0.067 µH	0.22 µH
L5	0.16 µH	0.16 µH	w.l.
IC1	MM 57105	MM 57100 or MM 57106	MM 57105
IC2	MM 53114	MM 53104	MM 53114
crystal	4.433618 MHz	3.579545 MHz	4.433618 MHz

– = omit;
w.l. = wire link.
+ All capacitors marked + should be NPO types. Note that C17 and C19 should be 2 . . . 27 p trimmers if self-wound air coils are used for L2 and L3 (see text); for the PAL UHF version C19 is 33 p (fixed) in this case.

2





Parts list to figures 1 and 2:

Resistors:
R1 = 470 Ω
R2 = 820 Ω
R3 = 180 k
R4,R6,R8 = 2k2
R5,R7 = 15 k
R9 = 5k6
R10 = 6M8
R11 = 3k3
R12,R13 = 1 k
R14,R15 = see Table 1
R16 = 100 Ω
R17,R18,R23,R24 = 220 Ω
R19,R20,R22 = see Table 1
R21 = see text and Table 1
P1,P2 = 470 k (lin) potentiometer

Capacitors:
C1 = 1000 µ/25 V
C2 = 10 µ/16 V
C3,C4,C8,C9,C16,
C20,C21 = 10 n
C5 = 1 µ/25 V
C6,C7 = 100 n (see text)
C10+ = 4p7
C11+ = see Table 1
C12+ = 47 p
C13 = trimmer 6 . . . 45 p
C14+,C15+ = 47 p
C17+,C19+ = see text and Table 1
C18,C22+,C23+,C24,C25,
C26+,C27+ = see Table 1

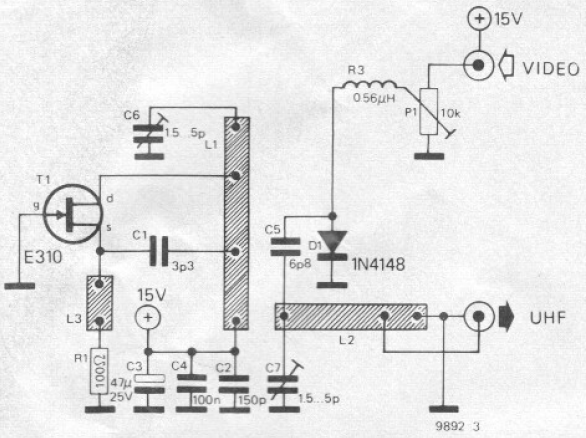
Coils:
L1 = 7 . . . 10 µH (Toko 7 A6199 or equ.)
L2 = see Table 1
L3 = 0.056 . . . 0.076 µH (Toko M 20070 or equ.) or self-wound air coil (see text)
L4 = 0.067 µH (Toko 521 GN-3T or equ.) or self-wound air coil (see text and Table 1)
L5 = 0.16 µH (Toko 521 GN-6T or equ.) or self-wound air coil (see text and Table 1)

Semiconductors:
T1 = BC 557B,BC 177B, or equ.
IC1,IC2 = see Table 1
IC3 = LM 1889
IC4 = LM 341-15
B = B 40C800 (bridge rectifier)

Miscellaneous:
Tr = transformer 18 V/150 mA
S1,S2 = switch SPDT (S1 not required for PAL UHF version)
S3,S4 = pushbutton switch SPST
coaxial socket 60 Ω (or 75 Ω)
quartz crystal, see Table 1
fuse 50 mA

Note: capacitors marked + should preferably be NPO types.

3



Parts list to figures 3 and 4:

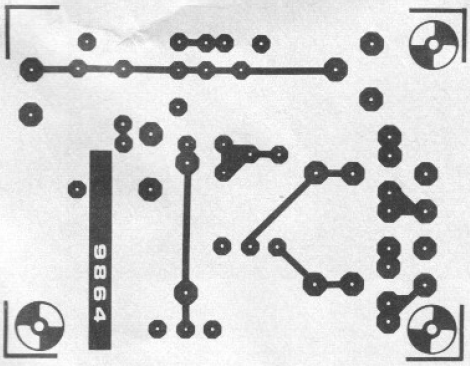
Resistors:
R1 = 100 Ω
R2,R3 = 3k9
P1 = 10 k preset
P2 = 1 k preset

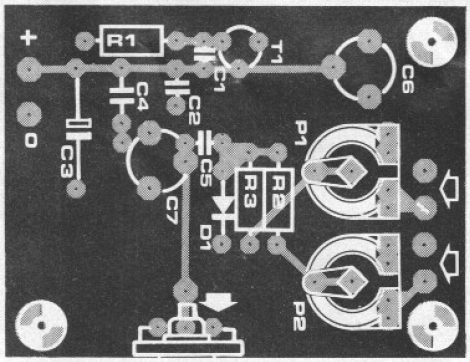
Capacitors:
C1 = 3p3
C2 = 150 p
C3 = 47 µ/25 V
C4 = 100 n
C5 = 6p8
C6,C7 = trimmer 1.5 - 5 p

Semiconductors:
T1 = FET E 310
D1 = 1N4148

Miscellaneous:
L1,L2,L3 = striplines on p.c.board

4





VHF band. This output is suitable as it stands for use on the European continent. However, in Great Britain 'up-conversion' to the UHF band (channels 21 . . . 68) is required, and a suitable circuit will be described further on.

The frequency of the sound carrier is determined by the resonant circuit L1/C11, and can be tuned exactly by means of L1.

By lowering the value of capacitors C6 and C7 it is possible to reduce the range over which the bats may be moved up and down on the screen.

The −15 V and −9 V supply voltages which are needed for IC1 . . . IC3 are obtained by means of a 15 V voltage regulator (IC4) and transistor T1. The regulator should be fitted with a heat sink. The metal housing of the game can also be used as a heat sink if the tab of the regulator is insulated using a mica washer. At 150 mA, the current consumption of the circuit is relatively small. Any transformer with a secondary voltage of 18 V will prove suitable.

Construction, general comments

A suitable printed circuit board design is given in figure 2. Regrettably, there is a minor error in the component layout: the indications 'GS' (Game Select) and 'Reset' at the right-hand edge of the board are transposed. When constructing the circuit the use of IC sockets is strongly recommended. IC2 is particularly sensitive to static charge and the appropriate precautions should be taken.

To prevent the circuit producing too much RF interference it should be housed in a screened metal case. The only earth connection between the board and the metal case should be at the coaxial output socket (see photo 1). The leads between the socket and the RF output on the board should be as short as possible. If the basic VHF version is used then R22 and C27 should be soldered direct to the socket.

The cables to the control handsets and the 'Reset' and 'Game Select' switches are not critical, so they need not be screened. A 60 Ω coaxial cable should be used to connect the output socket to the TV aerial input.

The description given so far has been sufficiently general to be basically valid for all versions of the game. However, when it comes to actually getting it to work in various parts of the world each version must be dealt with separately. For most of the European continent (with the notable exceptions of U.K., Ireland and France) the basic PAL VHF system is required. For the United States and Canada there is a similar NTSC VHF system. The U.K. and Ireland, however, need a PAL UHF version. All three versions will now be dealt with individually.

PAL VHF version

The circuit diagram given in figure 1 is valid for the PAL VHF version of the game. The various frequencies required are as follows:

Sound channel:	5.5 MHz;
Colour frequency:	4.43361875 MHz;
Channel 3:	55.25 MHz;
Channel 4:	62.25 MHz.

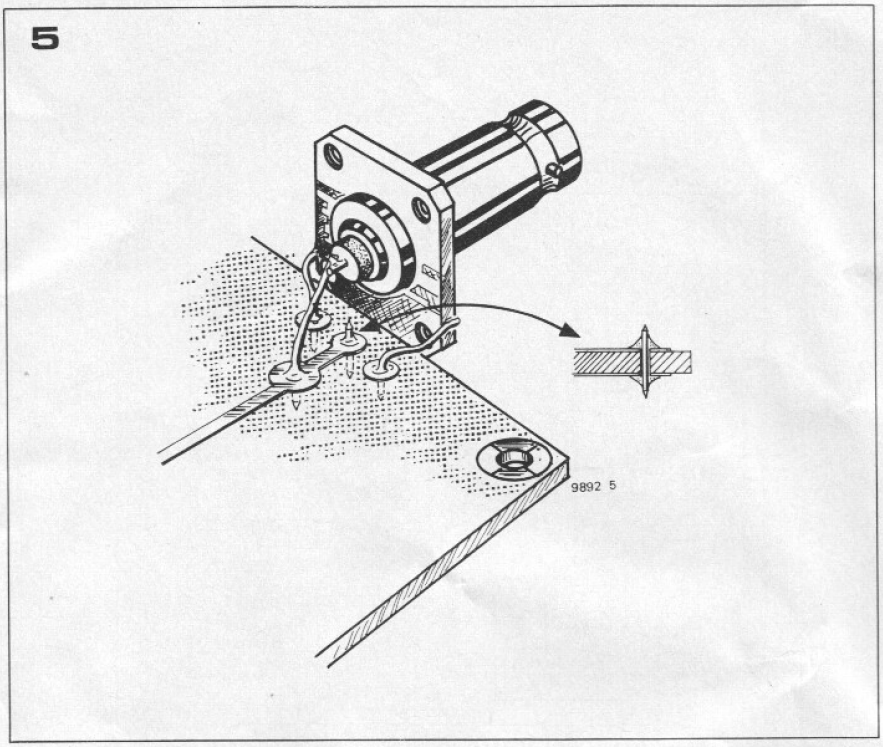


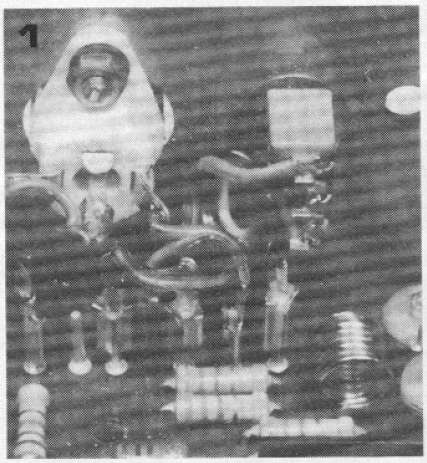
Figure 3. Complete circuit of the UHF modulator. L1, L2 and L3 are so-called striplines etched on the printed circuit board.

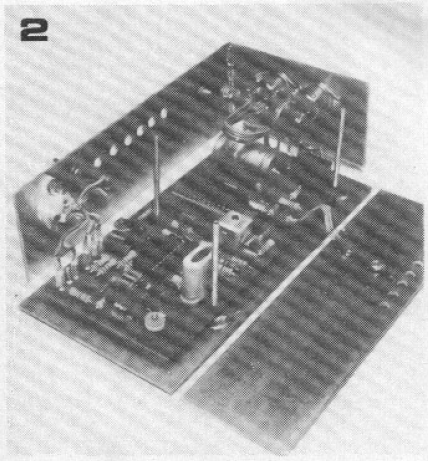
Figure 4. Printed circuit board and component layout for the UHF TV modulator (EPS 9864).

Figure 5. Note the (arrowed) connection between the 'cold' end of stripline L2 and supply common on the modulator board.

Photo 1. This photo shows how the connection is made between the RF output from the board, the coaxial output socket and the screened box. Note that this is only valid for the VHF versions of the game; for the PAL UHF version, a (similar) connection must be made at the RF output of the modulator board instead.

Photo 2. Construction of the printed circuit board and metal case.





The necessary IC types and component values can be found from the parts list and Table 1.

Tuning the circuit should not present too much of a problem:

- First tune the TV receiver to channel 3 in the VHF waveband, switch S1 to 'channel 3', then adjust L3 (or C19) until the picture appears on the screen. The TV channel control can then be used to provide fine adjustment.
- If the input sensitivity of the receiver proves insufficient (so that there is too much noise or 'snow' in the picture), then the value of resistor R21 should be reduced.
- Adjust C13 until a colour picture is obtained.
- Tune the TV receiver to channel 4 in the VHF waveband, switch S1 to 'channel 4', then adjust L2 (or C17) until the colour picture appears on the screen. Once again, the TV channel control can be used for fine adjustment.

Note that if a strong local broadcast transmitter is operating on the same frequency, then this may cause 'ghosting' or even poor synchronisation. To check for this, switch off the TV games unit, leaving it connected to the receiver. If a (weak) picture from the broadcast transmitter is now visible, the TV channel control can be used to tune it out. The TV games unit is then switched on again and L2 or L3 (or C17 or C19) is readjusted until the colour picture is once again obtained.

- To tune in the sound carrier, the volume control on the receiver is turned up a little and L1 is then adjusted until the noise from the loudspeaker is reduced to a minimum.

NTSC VHF version

For the NTSC version, the circuit diagram shown in figure 1 is basically correct. However, several component values and IC types should be modified as detailed in Table 1. The various frequencies required in this case are as follows:

Sound channel: 4.5 MHz;
Color frequency: 3.579545 MHz;
Channel 3: 61.25 MHz;
Channel 4: 67.25 MHz.

The alignment procedure is identical to the procedure outlined above for the PAL VHF version.

A special problem exists in the United States: the FCC regulations. These are among the most stringent in the world, and in order to comply with them extreme care must be taken when constructing the unit. Extensive details are given in the National Semiconductor publication number FEPM-0034/377 (CN-1) and only a brief summary can be given here.

The complete unit, with the possible exception of the player handsets and Game Select and Reset pushbuttons, must be housed in an RF-tight enclosure. This enclosure can be made from galvanized or tin-plated steel, or from printed circuit board material. All corners should be tightly formed and preferably soldered, allowing no gaps which could result in RF leakage; a tight-fitting lid is absolutely necessary.

Feed-through capacitors should be used in the connections to the player control

handsets, Game Select and Reset pushbuttons, and power supply connections.

To fully comply with FCC regulations, a TV game antenna switchbox should be used. This is basically a selector switch, be means of which it is possible to select either the TV game signal or the normal antenna; it must provide a minimum of 60 dB isolation to the non-selected input. These units can be purchased as a sub-assembly from various suppliers, however for the home constructor a much cheaper solution is to plug the desired programme source into the TV set . . .

The only other regulation that needs to be considered here states that all RF signals appearing more than 3 MHz outside the standard TV channel band must be attenuated by at least 30 dB relative to the peak envelope power of the wanted RF signal. There are two ways of meeting this demand. The first (and easiest) is to tune the unit approximately 1.5 MHz high with respect to the standard TV channel frequencies. The channel 3 and 4 outputs are thus tuned to 62.75 MHz and 68.75 MHz respectively. The second possibility is to replace the output filter (R19 . . . R22, C22 . . . C27, L4 and L5) by a so-called Surface Acoustic Wave filter and one or two other components. Full details of this modification are given in the National Semiconductor publication mentioned earlier.

PAL UHF version

For use in the UK and Ireland, a few modifications are required to the basic PAL VHF version. Furthermore, a VHF-to-UHF converter must be added. The required frequencies are as follows:

Sound channel: 6.0 MHz;
Colour frequency: 4.43361875 MHz;
Output frequency: 470 . . . 500 MHz (channels 21 ... 25).

The necessary IC types and component values can be found from the parts list and Table 1. Components R14, R15, C17, C18, L2 and S1 may be omitted; the top of R16 is connected to the R17/R18/C20 junction by means of a wire link (in place of S1). L3 may be set in the middle of its range; if a self-wound air coil is used (as described earlier) C19 may be replaced by a 33 p fixed capacitor, since the VHF output frequency is unimportant and need not be adjusted.

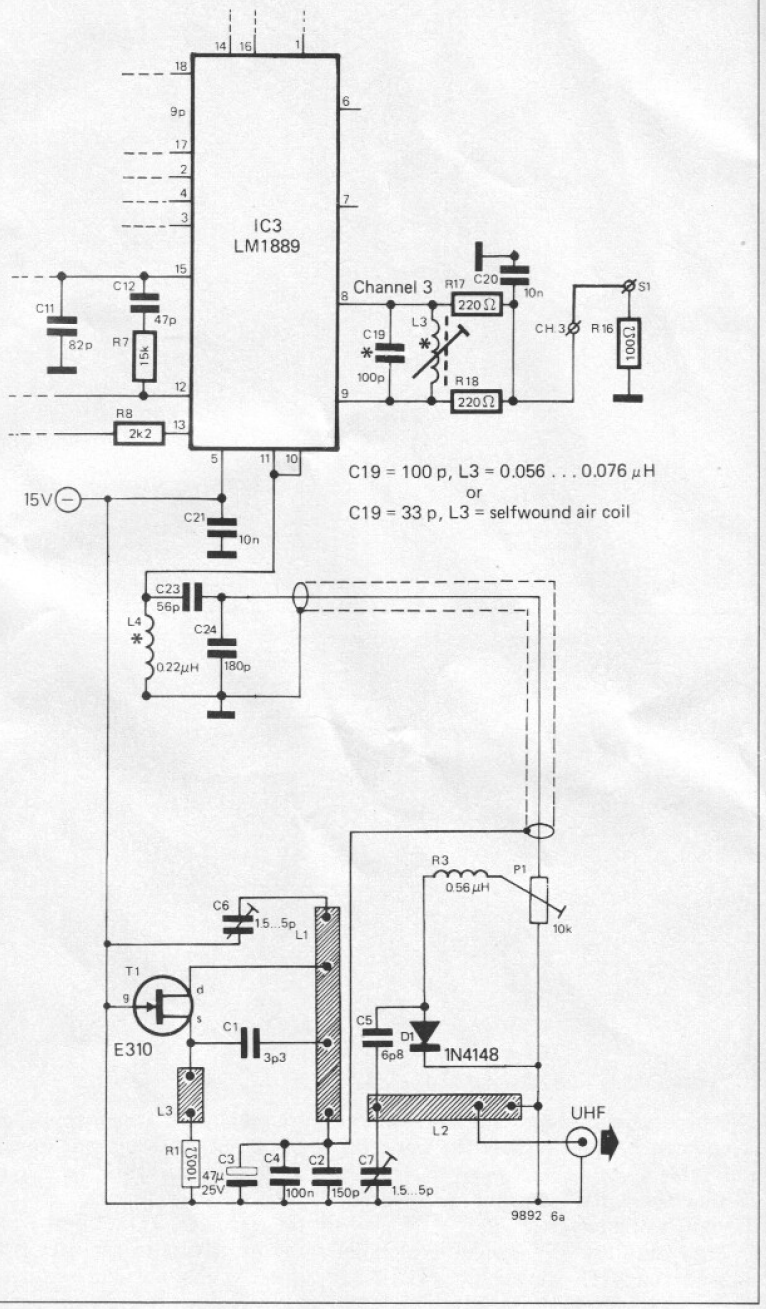
The output filter can also be simplified: R19, R20, R22, C22 and C25 . . . C27 are omitted, L5 and R21 are replaced by wire links, L4 becomes 0.22 µH (or a self-wound air coil consisting of 9 turns), C23 becomes 56 p and C24 becomes 180 p.

A suitable circuit for a VHF-to-UHF converter was published in Elektor 32, December 1977, p. 12-20: the UHF TV modulator. One or two minor modifications are required: R3 is replaced by a 0.56 µH inductor and R2 and P2 may be omitted. The modified circuit is shown in figure 3, and the printed circuit board and component layout are given in figure 4. As stated in the original article, home production of this p.c.board is not recommended. It should also be noted that the components are mounted on the same side of the board as the copper track pattern. It is absolutely essential that all component leads should be as short as possible.

One important detail could not be made clear on the component layout: the right-hand end of stripline L2 should be connected to supply common on the board, as shown in figure 3. This is achieved by inserting a piece of wire in the hole underneath the coaxial socket, and soldering it to both sides of the p.c.board (see figure 5). It is strongly recommended to do this *before* mounting the socket!

When interconnecting the boards, careful attention should be paid to the power supply connections. The TV games board has 'supply common' and '−15 V' outputs, whereas the UHF modulator requires 'supply common' and '+15 V' inputs. To achieve this, the supply common output from the TV games board must be connected to the '+15 V' input on the modulator board, and the '−15 V' output from the TV games board must be connected to 'supply common' on the modulator board. In other words, supply common on one board is *not* 'supply common' on the other!

6a



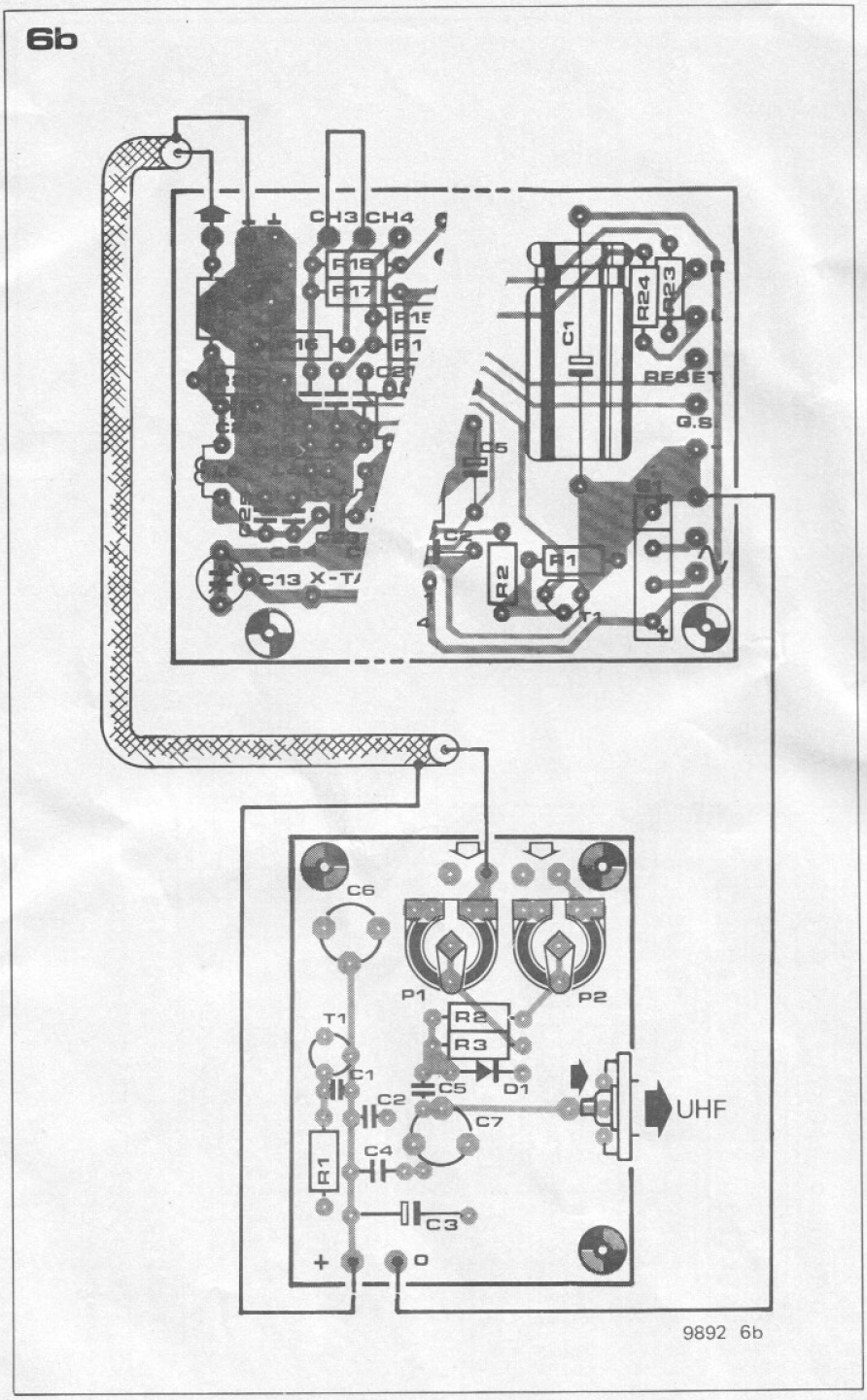


Figure 6. Interconnection details for the two boards.

The correct way to interconnect the two boards is shown in figure 6. In figure 6A, the upper part of the circuit shows IC3 and the modified output filter section on the TV games board; the lower part is the (modified) circuit of the UHF modulator. The three connections between the two boards are shown in figure 6B: the output of the TV games board is connected to one input of the modulator board via coaxial cable; the screen of the coax is connected to supply common on the TV games board and *to the '+' input* of the modulator board; the '–' output of the TV-games board is connected to the '0' input of the modulator.

Both units should be mounted inside a screened box. A 75 Ω BNC or TV coaxial socket can be used as the UHF output connector, and it should be mounted directly on the modulator board in the position shown. The ground connection between the circuit and the screened box must be made only at this output socket. Note that this implies that the box is connected to the '–15 V' supply of the TV games board, not its 'supply common'!

The alignment procedure in this case is as follows:

- Tune the TV receiver to an unoccupied frequency at the 'low' end of the UHF band – i.e. near channel 21.
- Set P1 on the modulator board to maximum (fully anti-clockwise).
- Starting from the minimum capacitance setting of C6 on the modulator board, adjust this trimmer slowly until a clean TV games picture appears on the screen. Note that the modulator produces two strong sidebands, a strong carrier, and several weaker sidebands. Only one of these is the correct signal!
- Adjust C7 on the modulator board for maximum signal strength.
- If necessary, turn back P1 on the modulator board to reduce the signal strength.
- Adjust C13 on the TV games board until a satisfactory colour picture is obtained.
- To tune in the sound carrier, turn up the volume control on the receiver and adjust L1 until the noise from the loudspeaker is reduced to a minimum.